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OPINION

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On the political feasibility of climate change mitigation pathways: Is it too late to keep warming below 1.5°C?

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Abstract

Keeping global warming below 1.5°C is technically possible but is it politically feasible? Understanding political feasibility requires answering three questions: (a) "*Feasibility of what*?," (b) *"Feasibility when and where?*,*"* and (c) *"Feasibility for whom?*.*"* In relation to the 1.5°C target, these questions translate into (a) identifying specific actions comprising the 1.5°C pathways; (b) assessing the economic and political costs of these actions in different socioeconomic and political contexts; and (c) assessing the economic and institutional capacity of relevant social actors to bear these costs. This view of political feasibility stresses costs and capacities in contrast to the prevailing focus on benefits and motivations which mistakes desirability for feasibility. The evidence on the political feasibility of required climate actions is not systematic, but clearly indicates that the costs of required actions are too high in relation to capacities to bear these costs in relevant contexts. In the future, costs may decline and capacities may increase which would reduce political constraints for at least some solutions. However, this is unlikely to happen in time to avoid a temperature overshoot. Further research should focus on exploring the "dynamic political feasibility space" constrained by costs and capacities in order to find more feasible pathways to climate stabilization.

This article is categorized under:
The Carbon Economy and Climate Mitigation > Decarbonizing Energy and/or Reducing Demand

KEYWORDS
political feasibility, climate change mitigation, decarbonization pathways, integrated assessment models

1 | INTRODUCTION

Keeping global warming below 1.5°C is a race against time. Is it too late to win?

Answering this question is a matter of imagination, math and politics. The most widely used tools to imagine the future and find pathways to meet climate goals are integrated assessment models (IAMs). IAMs represent geophysical, energy and economic systems and their interconnections and can tell us not only how fast emissions need to be reduced to keep global warming under 1.5°C, but also which technologies and in what combinations can achieve these reductions. Is it feasible to introduce and scale up such technologies fast enough? IAMs use "geophysical dimensions and technological and economic enabling factors" (Rogelj et al., 2018, p. 98) to rule out pathways that are not feasible. "Infeasibility [in IAMs] is … an indication that under a specific model parameterization the transformation cannot be achieved. It provides a useful context to understand technical or economic concerns … but need[s] to be … differentiated from … feasibility … in the real world, which hinges on a number of other factors, such as political and social concerns that might render feasible model solutions unattainable in the real world" (Riahi et al., 2015, p. 19).

Surely, "feasible model solutions unattainable in the real world" are of little use for keeping warming below 1.5°C. Unfortunately, there is a wide gap between the real-world climate action and what is required for stabilizing the climate at safe levels (Climate Action Tracker, 2019; Rogelj et al., 2016; UN Environment, 2018). As climate advocates urge policy makers to close this gap before it is too late, a key question for scientists is whether the required policies are feasible.

What makes a policy unfeasible are constraints which are outside of the control of a policy maker (Majone, 1975; Schubert, Thuß, & Möst, 2015). Such constraints can be different in nature. Cherp, Vinichenko, Jewell, Brutschin, and Sovacool (2018) argue that low-carbon energy transitions involve co-evolutionary changes in technoeconomic (energy flows and markets), sociotechnical (knowledge and social practices), and political (policy action) systems. A climate action can be rendered infeasible by constraints within any of these systems: a shortage of resources, lack of suitable technologies, or opposing political interests (Box 1). Without claiming that the 1.5°C pathways in IAMs represent all relevant technoeconomic and sociotechnical constraints, in this paper we focus on *political* constraints which have not been systematically represented and are the most underexplored.

Box 1: What determines the political feasibility of decarbonization?

Whether we can keep global warming below 1.5°C mostly depends on political rather than technical factors. Political feasibility is not a question of the political will to undertake a single action but rather a matter of our ability to intervene in the economy in a myriad of interdependent ways. Some of these interventions and their combinations are more politically feasible than others: for example, it is usually easier to expand low-carbon industries which create jobs and economic opportunities than to phase-out carbon-intensive sectors thus hurting employment and stranding assets.

Political feasibility of climate interventions also depends on their geographic and socioeconomic context. It is easier to impose a carbon tax in Sweden, where the electricity system is decarbonized and energy makes up a smaller proportion of household spending than in Indonesia which relies heavily on coal power and where poor people spend much more of their income on energy. It is easier to build a nuclear power plant in China with its established nuclear energy industry than in Kenya which lacks nuclear infrastructure.

Finally, for a climate intervention to be politically feasible, there must be a path for actors to achieve this intervention. This is a function of national economic and institutional capacities as well as international collaboration. Public and private actors in some countries are more capable than others of bearing higher political and economic costs of decarbonization. In particular governments that lead climate action tend to have significant economic resources and are also supported by political systems which make them less dependent on vested interests that stand to lose from rapid transitions.

Political philosophers define an outcome as politically feasible if there is an agent or group of agents who have the capacity to carry out a set of actions which will lead to that outcome in a given context (Gilabert & Lawford-Smith, 2012). There are three important ideas embedded in this concept. The first is the distinction of a set of *actions* leading to the desired outcome; the second is the influence of the policy *context*[1]; and the third is the importance of *actors*. To evaluate the political feasibility of any given policy or pathway, these three components can be explored with three questions: "Feasibility of what?," "Feasible when and where?," and "Feasible for whom?" (Gilabert & Lawford-Smith, 2012, p. 812). Let us look into these questions with respect to achieving the 1.5°C target.

2 | FEASIBILITY OF WHAT?

What exactly needs to happen to achieve the 1.5°C target? Whether it is politically feasible to keep global warming under 1.5°C may come across as a fairly straightforward question which boils down to whether there is political will for a dramatic intervention. However, what should be evaluated is not a single intervention but an extensive portfolio of measures leading to necessary changes in the energy, land and other sectors. IAMs are invaluable because they make it possible to unpack political feasibility of achieving a single global target into many concrete questions such as: is it feasible to phase-out coal in electricity by 2050? or to grow the share of renewables in electricity to over 60% by 2050? (Both observed in the majority of 1.5°C scenarios (Huppman et al., 2018; Intergovernmental Panel on Climate Change [IPCC], 2018; Rogelj, Shindell, et al., 2018).

The different "what's" comprising decarbonization pathways have received unequal attention in the literature. It is more common to study the feasibility of expanding low-carbon technologies (Loftus, Cohen, Long, & Jenkins, 2015; van Sluisveld et al., 2015; C. Wilson, Grubler, Bauer, Krey, & Riahi, 2013), but meeting stringent climate targets also requires phasing-out carbon-intensive sectors,[2] possibly deploying negative emission technologies and radical energy demand reduction as well as many other actions (IPCC, 2018; Rogelj et al., 2018; Rogelj, Shindell, et al., 2018). The "what" question should not only address these actions, but also their interactions for example, the feasibility of simultaneously expanding low-carbon energy supply and reducing the overall energy demand.

3 | FEASIBLE WHEN AND WHERE?

Under which circumstances could the necessary climate action take place? Political feasibility is context dependent (Gilabert & Lawford-Smith, 2012) which means that climate action which is feasible in one place may not be feasible elsewhere. This is highly relevant for determining the feasibility of pathways towards a climate-safe future, which will unfold in a highly heterogenous world comprised of many different countries.

Historically, the adoption of new energy technologies has been uneven between countries and regions which make up the "core" (where a technology is first introduced), the "rim" (where a technology initially diffuses) and the "periphery" (where a technology diffuses last) (Grubler, 1992, 1998; Wilson, 2012). Low-carbon energy technologies are no exception: Jewell (2011) found that nuclear energy has been primarily introduced in relatively large, wealthy and rapidly growing economies and Vinichenko (2018) shows that solar and wind power is introduced earlier in high-income Organisation for Economic Co-operation and Development (OECD) countries. The higher cost of borrowing capital in lower- and middle-income countries may disadvantage renewables (Schmidt, 2014) and slow down their adoption as compared to high-income countries.

National contexts influence not only the feasibility of expanding low-carbon technologies, but also the feasibility of phasing out carbon-intensive sectors such as coal power. The Powering Past Coal alliance (PPCA) is dominated by countries that produce and use less coal, have older power plants, and where electricity demand is stagnating or declining (Jewell, Vinichenko, Nacke, & Cherp, 2019). This is not surprising given that countries with more coal, younger power plants or faster demand growth face higher costs of coal phase-out ranging from potential stranded assets and loss of employment to the need to invest in alternative sources.

4 | FEASIBLE FOR WHOM?

Which actors are capable of implementing the required climate actions? Political feasibility also requires the presence of actors capable of bringing about the desired outcome. For example, deployment of wind power required involvement of regulators, electric utilities, investors, turbine manufacturers, installation and construction companies, as well as local authorities, land-owners and residents (Bergek & Jacobsson, 2003; Mizuno, 2014). Such actors are more likely to be found in wealthier, technologically-advanced and effectively-governed countries with a dynamic private sector and robust financial systems. In other words "*feasibility for whom?*" is related to *"feasibility when and where?"*

However, these questions are not identical. Similar outcomes can be brought about by different constellations of actors. For example, farmers' cooperatives and domestic equipment manufacturers prominent in the uptake of wind power in

Germany and Denmark have not played a significant role in the United Kingdom, where wind power has been deployed primarily by electric utilities and the equipment has been largely imported (Geels et al., 2016). Furthermore, actors capable of bringing about energy transitions can be located not only within but also outside national borders. Indeed, deployment of new energy technologies in most countries has historically involved international actors who provided equipment, knowledge and finance. For example, German companies support wind power in many countries, such as Uruguay (Cherp, 2015; Watts, 2015) and similar support has been received by China and other developing countries (Lewis, 2013; Suzuki, 2015).

More generally, Binz and Truffer (2017) explain how various actors (industries, consultancies, academia, non-governmental organizations) and their networks interact at several connected levels, from regional to global, to form Global Innovation Systems which facilitate both the evolution and uptake of clean energy technologies. In addition to technology innovation and diffusion, climate action has relied on international diffusion of norms and policies involving political actors both within and outside of national borders. For example, the European Union established policy targets and facilitated policy learning and import of technology triggering the rapid introduction of renewable electricity in its new member states (Schaffer & Bernauer, 2014; Vinichenko, 2018).

On the other hand, companies from China and Japan facilitate the construction of coal power plants in many developing economies in Asia (Shearer & Buckley, 2019; Sugiura & Okutsu, 2019). And Russia is currently the main supplier of nuclear power equipment often backed by financial export guarantees (Brutschin & Jewell, 2018; Jewell, Vetier, & Garcia-Cabrera, 2019). It is not surprising that many of recent nuclear newcomers (most notably Bangladesh, Belarus and Turkey) are constructing their first nuclear power plants with financial support from the Russian state and involvement of the state-owned nuclear supplier Rosatom. Similarly, China is planning to export up to 30 nuclear power units to the Road and Belt Initiative countries (Tabeta, 2019). Thus, both national and international actors are likely to play significant roles in the deployment of low-carbon technologies.

5 | COSTS, CAPACITIES, AND CONSTRAINTS

Understanding actors involved in climate action is necessary for operationalizing the concept of *constraints* prominent in both climate change stabilization pathways and in the definitions of political feasibility. A constraint is only meaningful when referring to a specific actor whose action is constrained. For example, an investor considering a renewable energy project is constrained by the project's profitability while a policy maker considering a ban on coal power is constrained by the potential loss of employment among her electorate.

Obviously, climate actions may be constrained by their high costs, which are often calculated in IAM-generated scenarios (McCollum et al., 2018; Tavoni et al., 2015). Yet these costs do not fully address the political feasibility of climate mitigation

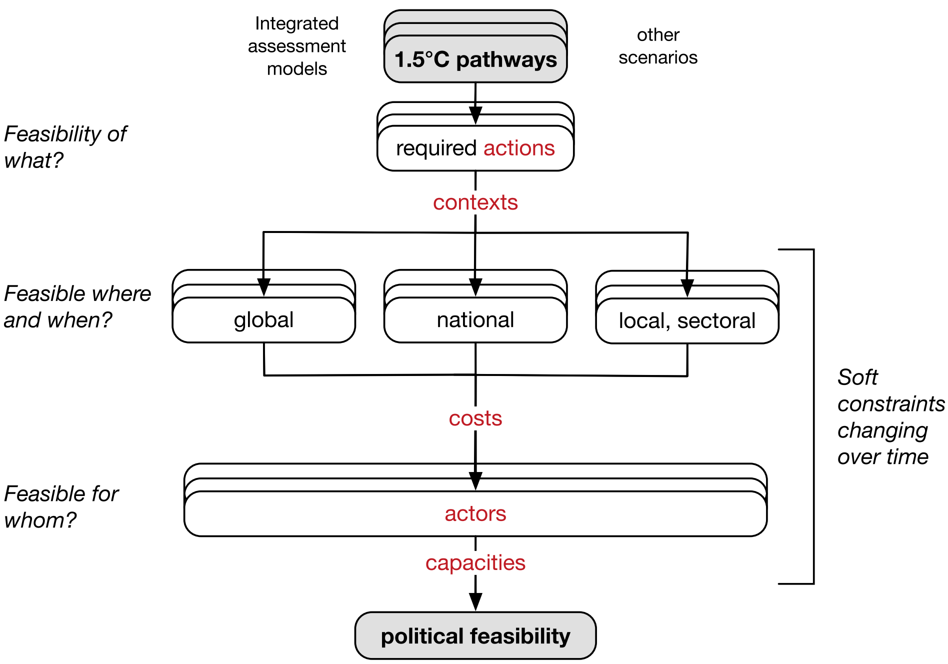

FIGURE 1 A framework for evaluating political feasibility of decarbonization pathways. The framework addresses the three key questions of political feasibility: Feasibility of what? Feasible when and where? and Feasible for whom? by systematically identifying the required decarbonization actions in 1.5°C pathways, their context, the relevant actors, the political and economic costs that the actors would face and the actors' capacities to bear these costs

for three reasons. First, IAMs primarily calculate *economic* costs such as reduced consumption or increases in needed investment whereas political feasibility also depends on *political* costs such as lost votes and reduced energy security. Second, IAMs aggregate costs, either for the world as a whole or global-regions, whereas what matters for political feasibility are disaggregated costs to relevant actors, such as national politicians or international investors. Third, whether a cost becomes a constraint for a particular actor depends on the actor's political and economic *capacity* to bear this cost. Political or institutional capacity is the ability to see through a policy given the presence of diverse interests; it can be signaled by the quality of governance and political stability. Economic capacity is the availability of resources to support low-carbon technologies or to compensate for losses incurred by phasing out carbon-intensive technologies.

The interplay of costs and capacities in defining the feasibility of a climate action is illustrated by Jewell et al.'s (2019) analysis of worldwide pledges to phase out coal power within the PPCA. They show that whether a country adopts such a pledge is explained by both the costs of coal phase-out (countries with older power plants and lower domestic extraction and use) and the capacity of a country to bear these costs, which is signaled not only by income per capita but also by a government's transparency and ability to act independently from private interests. The latter is especially important because vested interests, especially from fossil fuel sectors, may hinder energy transitions (Antal, In press; Cherp, Vinichenko, Jewell, Suzuki, & Antal, 2017; Geels, 2014; Moe, 2012).

The importance of political and economic capacity is illustrated by the recent "coal exit" plan in Germany, a country facing significant costs of coal phase-out due to a large share of coal in power generation, a sizeable coal-mining sector, and a relatively young coal power plant fleet. The German government has been able to negotiate coal exit with diverse political stakeholders and also committed to pay upward of €40 bln in compensation to affected communities with additional compensation to utilities still under negotiations (Jewell et al., 2019).

In Figure 1 we present a framework for evaluating political feasibility of decarbonization pathways which addresses the three questions and stresses the importance of costs to and capacities of relevant actors.

6 | REVIEWING THE EVIDENCE FOR POLITICAL FEASIBILITY OF 1.5°C PATHWAYS

The framework in Figure 1 enables us to systematically evaluate the evidence for the political feasibility of keeping global warming below 1.5°C. The bulk of such evidence relates to low-carbon energy supply. A number of studies show that the required growth in low-carbon energy technologies (at least with respect to 2°C pathways) is consistent with the historical growth of energy technologies, at least when measured in relation to the size of the energy system (Loftus et al., 2015; van Sluisveld et al., 2015; Wilson et al., 2013). Though encouraging, these studies say more about technoeconomic and sociotechnical rather than political feasibility, because most of these past technologies were introduced through technological innovation and market forces without strong political interventions (Fouquet & Pearson, 2012). In addition, this literature does not compare the contexts in which past energy technologies were introduced, their economic and political costs, and the capacities of relevant actors with the contexts, costs and capacities needed to expand low-carbon energy supply into the future.

The growing literature on the worldwide deployment of renewable electricity contains more specific and direct evidence for the political feasibility of decarbonization, since renewables play an important role in virtually all 1.5°C scenarios (IPCC, 2018; Rogelj, Popp, et al., 2018; Rogelj, Shindell, et al., 2018). The empirical literature on renewable energy growth documents uptake and rapid expansion of renewables, which is led by wealthy industrialized countries but followed by an increasing number of emerging economies (Baldwin, Carley, Brass, & MacLean, 2017; Carley, Baldwin, MacLean, & Brass, 2017; Vinichenko, 2018). To make a conclusive case that the rate of deploying renewables required for the 1.5°C target is politically achievable it is necessary to project results from this literature into the future. In particular, we need to understand whether larger emerging economies would be capable of sustaining the rapid growth of renewables after they expand beyond the niche level.

The literature also contains contested evidence on political feasibility of deploying nuclear power, another low-carbon option prominent in some climate mitigation pathways. One group of scholars believes that the rapid historical expansion of nuclear power in France, Sweden and some other countries indicates the feasibility for its rapid deployment elsewhere (Cao, Cohen, Hansen, Lester, Peterson, Qvist, et al., 2016; Cao, Cohen, Hansen, Lester, Peterson, & Xu, 2016). Another group argues the recently low global rates of nuclear power expansion rule it out as a viable decarbonization solution (Lovins, 2016; Lovins, Palazzi, Laemel, & Goldfield, 2018). Neither argument explicitly addresses the "where", "when", or "for whom" questions: while the former assumes that what was feasible in Western Europe in the 1970s–1980s would be feasible in the rest of the world in the 21st century, the latter ignores national contexts all-together. This is in contrast to the empirical evidence that the introduction of nuclear energy is significant constrained by socioeconomic and political factors (Fuhrmann, 2012; Gourley & Stulberg, 2013; Jewell, 2011).

Another key decarbonization action is coal power phase-out. In most 1.5°C scenarios the use of unabated coal power should significantly decline by 2030 and drop to zero by mid-century (Luderer et al., 2018; Rogelj, Shindell, et al., 2018). At the same time there are significant political and economic constraints for phasing out carbon-intensive sectors that can trigger job losses and resistance from incumbents (Spencer et al., 2018) and there is no historical evidence that energy technologies have ever contracted on the global scale with such speed. In 2017, over 50 countries cities and states joined the PPCA to pledge to phase out unabated coal power, but this action will less than 1% of the emissions committed from the already operating coal power plants worldwide (Jewell et al., 2019). Moreover, the PPCA members mostly have power plants older than 35 years, generate less than 20% of their electricity from coal, have high per capita income and more transparent governments (Jewell et al., 2019). This means that they have lower costs and higher capacities for coal phase-out than, say, China, where almost half of global coal power is today, and whose power plants are on average 12 years old, supplying about 70% of China's electricity, has lower income per capita and a less transparent government. Similar observations are applicable to Vietnam, Indonesia, Malaysia, and other rapidly growing Asian economies with growing reliance on coal (Jewell et al., 2019).

On the demand side, the sustained energy intensity improvements implied in many stringent decarbonization scenarios are historically unprecedented (Loftus et al., 2015). Declines in energy intensity that match or exceed economic growth (thus leading to stagnant or declining energy demand) are especially difficult to attain due to the rebound effect, which is hard to control by policy measures. While the "low demand scenario" featured in the IPCC 1.5°C report (Grubler et al., 2018) offers a new pathway of scaling up best practices of demand reduction, there is no research on the political feasibility of transferring these practices to diverse contexts or on the malleability of rebound effect.

The remaining components of 1.5°C degree pathways can be divided into two groups. The first group includes solutions which are technically and economically feasible and which have already been successfully used in some contexts, for example electric vehicles, changes in industrial processes, low-carbon urban solutions, carbon pricing, forestry and land-use. There are inventories of "good practices," and scenarios calculate the impacts of extrapolating such practices worldwide (Kriegler et al., 2018; Roelfsema et al., 2018). There is, however, virtually no research on their historic analogues or on how different contexts affect their implementation. Thus, this approach does not address "feasibility when and where?" or "for whom?" by assuming that these practices will be socially and politically feasible worldwide. The second group includes negative emission technologies and other solutions with no widespread application beyond demonstration projects. With their technical feasibility still in question, there is even less evidence of their political feasibility, though it has been problematized in the literature (Anderson & Peters, 2016; Bäckstrand, Meadowcroft, & Oppenheimer, 2011; Fuss et al., 2014).

In summary, for key climate solutions that are already widely used, there is little evidence that they can be deployed worldwide at the scale and speed necessary for avoiding the 1.5°C overshoot. For other solutions, that are still only "best practices" or demonstrations, the evidence for political feasibility is even more scant. It should be added that even if climate solutions are politically feasible on their own it does not mean that they are feasible if implemented simultaneously. For example, most 1.5°C scenarios envision simultaneous demand reduction and expansion of low-carbon technologies, whereas in the past, new energy technologies such as nuclear power were expanded only during the periods of rapid electricity demand growth (Cherp et al., 2017; Jewell, 2011). Moreover, Patt, van Vliet, Lilliestam, and Pfenninger (2018) have argued that investments in energy efficiency risk crowding out or delaying other decarbonization policies and technological innovation. One important point they make is that implementing several solutions simultaneously may spread scarce political capital too thin thus diminishing the likely success of them all.

7 | SOFT AND DYNAMIC CONSTRAINTS, PROBABILISTIC FEASIBILITY

As discussed above, most evidence of political feasibility of climate action is derived from historic or present experience. However, if a certain solution or its analogues have not occurred in the past this does not necessarily mean that it is not politically feasible in the future. Many hope that the increasingly overwhelming dangers of climate change will eventually generate enough support for unprecedented political action. A related hope is that policy makers and the public will be persuaded to support stringent climate action by the numerous cobenefits of climate policies, such as cleaner air, green jobs, and increased energy security (Bain et al., 2016; Deng, Liang, Liu, & Anadon, 2017; Ürge-Vorsatz, Herrero, Dubash, & Lecocq, 2014). These arguments assume that strong motivation may compensate for low capacity and thus overcome constraints. However, contemporary political thought is more skeptical of the power of persuasion and asserts that desirability of certain outcomes does not necessarily translate into their feasibility (Gilabert & Lawford-Smith, 2012). Indeed, there is recent empirical

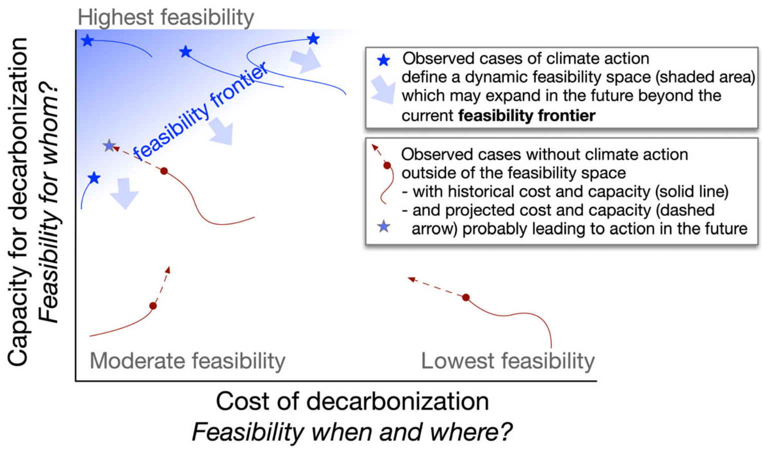

FIGURE 2 Dynamic political feasibility space. The figure shows how capacity and costs of decarbonization actions can be used to map dynamic political feasibility spaces with a feasibility frontier based on empirically observed phenomenon. The feasibility frontier will evolve over time as technologies, infrastructures and institutions evolve. The example space and feasibility frontier is generalized from Jewell et al. (2019)

evidence that "simply reframing" the climate discussion in terms of cobenefits is "unlikely to boost public support" (Bernauer & McGrath, 2016, p. 680).[3]

In some historical cases extremely strong motivations did compensate for low capacity. For example, even though large GDPs (over 50 billion USD) and political stability have historically been preconditions for nuclear power introduction in most countries, Pakistan, spurred on by India's nuclear bomb program mobilized enough resources to build a nuclear power plant when it had a GDP of only 13 billion USD and not long after a violent regime change (Jewell, 2011). Although in our experience, such situations are rare, they do illustrate an important point about political feasibility: in contrast to most "hard" constraints common in natural science and engineering, political constraints are "soft."

While hard constraints are deterministic and can exclude a solution on geophysical or technical grounds, soft constraints are probabilistic and often make a solution less feasible in economic or institutional terms without completely ruling it out (Gilabert & Lawford-Smith, 2012). In the above example, though wealth and political stability makes deployment of nuclear power more likely (Fuhrmann, 2012; Gourley & Stulberg, 2013; Jewell, 2011), this does not rule out nuclear power in poorer economies such as Pakistan. Similarly, we cannot rule out that China or India will phase-out coal power in the near future despite relatively high costs and lower capacity, we can only indicate that the probability of this occurring is low. The probabilistic nature of political feasibility means that it is most useful to evaluate it comparatively in order to identify which pathways may be more or less feasible (Gilabert & Lawford-Smith, 2012; Lawford-Smith, 2013) and also which enabling conditions may enhance the political feasibility of different pathways (Solecki et al., 2018).

The political feasibility of decarbonization pathways will likely significantly change over time as the evolution of the costs of and capacities for climate action continue to evolve. Resource depletion, infrastructure aging and innovation may reduce the costs of climate action. For example, governments may decide to phase-out coal after their coal resources are depleted (such as the United Kingdom as described in Turnheim & Geels, 2012) or the costs of competing energy sources such as shale gas and wind power decline (Larson, 2019; Nuccitelli, 2018). Declines in the costs of wind turbines, solar panels and electric vehicles, as well as the development of small modular nuclear reactors (Ramana & Mian, 2014) can make their adoption more feasible in developing countries even given high costs of capital and aversion to high prices. Of course, there is no guarantee that the costs of low carbon transitions always fall. The costs of nuclear power have been rising in some countries (Grubler, 2010; Koomey & Hultman, 2007; Koomey, Hultman, & Grubler, 2017), particularly due to more stringent regulation responding to public concerns about safety and waste. Similarly, at higher levels of penetration the added value of investment in renewables may decline, thus elevating their sociopolitical costs, even as the cost of the core technology falls (Wanner, 2019).

Capacities for climate action also evolve over time, for example due to increasing prosperity resulting in higher ability to bear the costs of climate action. This is an especially hopeful development if institutional capacities continue to correlate with economic wealth and the future brings not only higher incomes but also better governance which would make climate action more feasible. Capacities also evolve as a result of technology and policy learning which are often accelerated by international cooperation and policy diffusion (Cia Alves, Steiner, de Almeida Medeiros, & da Silva, 2019; Dinica, 2006; Zhou, Matisoff, Kingsley, & Brown, 2019). All this means that climate solutions are not only probabilistic, but also dynamic[4] (Figure 2). The question is whether this evolution will occur fast enough to beat the accumulation of greenhouse gases in the atmosphere (Box 2).

Box 2: Political feasibility of achieving the 1.5°C target: from historic evidence to future projections

The most straightforward way to judge political feasibility is by historic examples. If something has occurred in the past it makes it likely to occur in the future. France's and Sweden's rapid expansion of nuclear power in the 1970s–1980s, Denmark's deployment of wind power since the 1990s, and the recent commitment of over a dozen OECD countries to phase out unabated coal are examples of rapid decarbonization. Yet, the decarbonization required for 1.5°C must occur also outside Western Europe and beyond the OECD. At present, there are not enough actors capable of bearing the political and economic costs of these solutions at the required scale worldwide. Moreover, achieving the 1.5°C target requires solutions beyond nuclear power and coal phase-out: for example, constraining energy demand, carbon capture and storage and potentially deploying negative emission technologies. There is no evidence that any of these solutions are politically feasible at the required scale.

In the future, the costs of climate solutions may decrease and the capacities of relevant actors increase as illustrated in Figure 2. These changes in costs and capacities mean that at least those solutions that have already been observed historically may become possible for a wider range of countries. However, this shift in the **feasibility frontier** is not likely to happen in the next decade or so, which is required to stay within the 1.5° limit without overshoot.

The dynamic nature of political feasibility overtime is also shaped by more complex nonlinear dynamics (Pierson, 2004). On the one hand, as policies start benefiting certain social groups, support from these groups may ensure continuation and strengthening of these policies, which in turn increases the support base and further policy expansion. Thus, even initially costly policies may persist and expand. This phenomenon, known as "increasing returns," may be good news meaning low-carbon policies may be strengthened ("ratcheted-up") overtime as they benefit more actors (Pahle et al., 2018). On the other hand, a similar dynamic can also entrench, or lock-in, existing pro-carbon policies, such as fossil fuel subsidies long after they become ineffective in achieving their original goals (Inchauste & Victor, 2017) or constrain transformative policy change (Carey, Kay, & Nevile, 2019).

8 | CONCLUSIONS

To conclude, let us return to the gap which we highlighted in the beginning of the paper between current climate action and what is required to achieve the 1.5°C target. Whether and how soon this gap can be closed depends on why it exists in the first place. If it is the result of low awareness and weak motivation, it could be promptly closed by emphasizing the urgency of the climate problem and advocating for political mobilization. However, a systematic analysis of political feasibility suggests a different explanation: namely that there are currently not enough actors capable of bearing the costs of required decarbonization in specific national circumstances. This also means that the gap between real-life climate action and climate mitigation pathways can only narrow when the capacities of relevant actors sufficiently increase and/or the cost of decarbonization decreases. Can this happen and if so, would it be too late to meet the 1.5°C target?

The available evidence does not provide assuring answers, especially to the second question. The climate mitigation pathways modeled in IAMs includes actions which fall into three groups with respect to how much we know about their political feasibility. The first group contains solutions which have been already used and analyzed in diverse national contexts, for example renewables, nuclear and pledges to phase-out coal power. The knowledge about political constraints to these solutions is still far from complete but already indicative of the relevant actors, costs and capacities. We believe that these solutions will eventually become feasible at the required scale in most national contexts, but the necessary evolution of relevant actors, costs and capacities will almost definitely take more than one or two decades, that is, longer than the time we have to avoid temperature overshoot. The second group contains solutions for which we have best practice examples but no systematic comparative understanding about their implementation in various contexts. These include for example low-carbon mobility, sharing economy solutions, energy demand reduction, and decarbonization of industrial processes. Due to the lack of systematic evidence it is very difficult to judge the political feasibility of these solutions and its role in future developments. There is much to be gained by researching the capacities of relevant actors to implement these solutions in various contexts. The final group of solutions includes those that so far have not been commercially deployed including small modular nuclear reactors, carbon capture and storage, negative emission technologies and hydrogen-based fuels. Judging their political feasibility would be even more speculative before technoeconomic constraints are resolved.

In summary, the better known political constraints of solutions which are already extensively used worldwide are likely to prevent them to be deployed on the scale and in time to avoid overshooting 1.5°C. For solutions currently available only as "best practices" or demonstrations, the political constraints are simply not yet known. We also do not know much about the feasibility of implementing several challenging solutions simultaneously as required by decarbonization pathways.

We believe that the lack of evidence for political feasibility of decarbonization pathways should stimulate future research guided by systematic frameworks such as the one we propose here. Systematic evaluation of present and future political constraints would help to identify and concentrate scarce political capital on more politically feasible pathways and solutions. Even in the case of overshooting 1.5°C, and maybe especially so, we need to understand the feasibility of various decarbonization options including negative emission technologies. If the evidence against political feasibility of the 1.5°C pathways becomes overwhelming, it will also help us understand how warm of a world we need to prepare to live in.

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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ENDNOTES

[1] Majone (1975) talks about the need to consider how constraints are characterized in a specific decision-making context and time horizon.

[2] Decarbonization may include contraction of carbon-intensive industries but it can also maintain a similar industry structures and for example introduce carbon capture and storage to remove CO_2 emissions.

[3] Any analysis of co-benefits should always go hand-in-hand with an analysis of costs of achieving these benefits separately from climate policies (Garcia-Menendez, Saari, Monier, & Selin, 2015; Jewell et al., 2016).

[4] Gilabert and Lawford-Smith (2012) also discuss the dynamic nature of political feasibility in general.

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